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ABSTRACT

This analysis attempts to consolidate frequency studies done by public broadcasting, to compile some important characteristics of potentially available bands, and to prioritize the frequency options of public service users of satellite communications. Those bands are emphasized which facilitate the transfer of public service activities to operational rather than experimental status. Factors discussed include (1) available capacity, (2) interference with existing services, (3) co-location of terminals at point of use, (4) relative equipment costs, (5) technical constraints, (6) regulatory constraints, and (7) implications of government use. Operational satellites are currently available in only one of the frequency bands analyzed.
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A FREQUENCY STUDY FOR PUBLIC SERVICE USERS OF SATELLITE TELECOMMUNICATIONS

PUBLIC SERVICE SATELLITE CONSORTIUM
Technical Group

March, 1977

PREPARED FOR:

FEDERATION OF ROCKY MOUNTAIN STATES
2480 West 26th Avenue, Suite 300B
Denver, Colorado 80211
(Federation Prime Contract HEW-100-75-0092)

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I. INTRODUCTION

A. Background of Study

As part of the ATS-6 Health Education Telecommunications (HET) experiment, the Federation of Rocky Mountain States received a contract from DHEW to perform a technical evaluation. One of the additional tasks appended to this contract was to perform a frequency study of bands potentially available to public service satellite users.

In July of 1976 the engineering department of FRMS became the technical group of the recently organized Public Service Satellite Consortium. As a result a subcontract was signed between FRMS and PSSC with the consent of DHEW for PSSC to perform this frequency study.

B. Nature of Study

This analysis attempts to consolidate the frequency work done by public broadcasting, to compile some important characteristics of potentially available bands, and to prioritize the options of public service users of satellite communications.

C. Scope of Study

The frequencies considered here are all those bands potentially available under 14.5 GHz. The intent is to emphasize those bands which facilitate the transfer of public service activities to operational rather than experimental status. The factors involved are:

- available capacity
- interference with existing services
- co-location likelihood of terminals at point of use
- relative equipment costs
- technical constraints
- regulatory constraints
- implications of government use

D. Premises & Approach

At the time of this writing operational (vs. experimental) satellites are available in only one of the frequency bands covered in this analysis. Clearly, to impact on the issues of this study, a user must either have a requirement large enough to influence the configuration of new systems in the space segment, or the potential for aggregation with other users to form such a requirement. Otherwise the user would have no alternative but to accept some form of the services currently available.

II. EXPERIENCES OF PUBLIC BROADCASTING

A. History - The Decision to Use 4/6 GHz

A user with a requirement large enough to influence spacecraft design may elect to waive his option of choosing a new design in favor of an existing system. Factors of availability, technological uncertainty, cost, reliability, and timeliness of implementation, influence such decisions. For these and other reasons, Public Broadcasting has opted to use existing spacecraft operating at 4/6 GHz.

Besides being of interest to other users of the 4/6 GHz bands, Public Broadcasting's experiences will also provide some valuable insights into the consideration of other bands.

B. Video Interference Criteria at 4/6 GHz

The primary interference source for satellite receive-only terminals operating in the 4 GHz range (downlink) is the local terrestrial microwave link operating in the same band. Terrestrial links in this band utilize carrier spacings of 20 MHz. By positioning the satellite carriers ±10 MHz from adjacent terrestrial carriers, as in the PBS case, a minimum of 10 MHz carrier-to-carrier separation (desired-to-interfering signal) is assured. Under these

conditions, it has been determined that no perceptible interference to a video signal will result if the interfering signal level is 25 dB below the desired signal level. With this fact in mind PBS has established the following criteria:

a) for a single terrestrial interfering signal source

C/I ≥ 15 dB for all but 0.01% of worst month

≥ 20 dB for all but 0.1% of worst month

≥ 30 dB for all but 20% of worst month

b) for multiple (4) terrestrial signal sources

C/I ≥ 15 dB for all but 0.0025% of worst month

≥ 20 dB for all but 0.025% of worst month

≥ 36 dB for all but 20% of worst month

Interference due to precipitation scatter should be:

C/I ≥ 20 dB for all but 0.025 of worst month

C Probability of Co-location of the Receive-Only Terminals at the Point of Use

Co-location refers to the placement of a satellite terminal at the point where the signals are to be used. For a television station this would be at its studio. For medical uses, it might be at a hospital, or for educational purposes, it might be at a school. When the earth station cannot be co-located at the point of use, land must be purchased, a new building must be erected, utilities must be provided and a terrestrial microwave or cable relay must be purchased and installed to interconnect the earth station site with the point of use. The cost of the "terrestrial tail," when required, typically exceeds the capital cost of the satellite earth station.

Public Broadcasting and its prime contractor have expended considerable effort in making accurate estimates of co-location probablility. This analysis indicates that approximately (40%) of the proposed 150 sites would not be co-located. The initial PBS site examinations indicate the co-location projections were indeed quite accurate.

how close to ≤0% 6/77

Since the PBS sites include varying population densities, an interesting distribution can be plotted of sites projected as co-located against population density. Population here is taken as an indication of relative terrestrial microwave activity. The results are shown in Figure II-1. It appears that for locations having populations under 100,000 the probability of co-location is high but, in general, for greater populations it is low.

D. Technical, Regulatory & Economic Factors

A hallmark of the technology at 4/6 GHz is its maturity and hardware availability. This results in part from the extensive terrestrial use of these bands. Consequently, implementation of a system is possible in a shorter time frame than with other frequency bands, at this time. However, the density of terrestrial use causes potential interference problems and a corresponding delay in completing required frequency coordination. The costs of coordination and the often-necessary "terrestrial tail" result in higher overall system costs.

Another regulatory factor relates to the diameter of antennas useable in this band. Until recently the FCC required a minimum diameter of 10 meters. This is the size to be used at Public Broadcasting receive-only sites. However, in December 1976, the FCC gave permission to use 4.5-meter antennas for CATV distribution.[1] While such limitations greatly influence system costs, current

[1] ELECTRONICS, January 6, 1977, pp. 33,34.

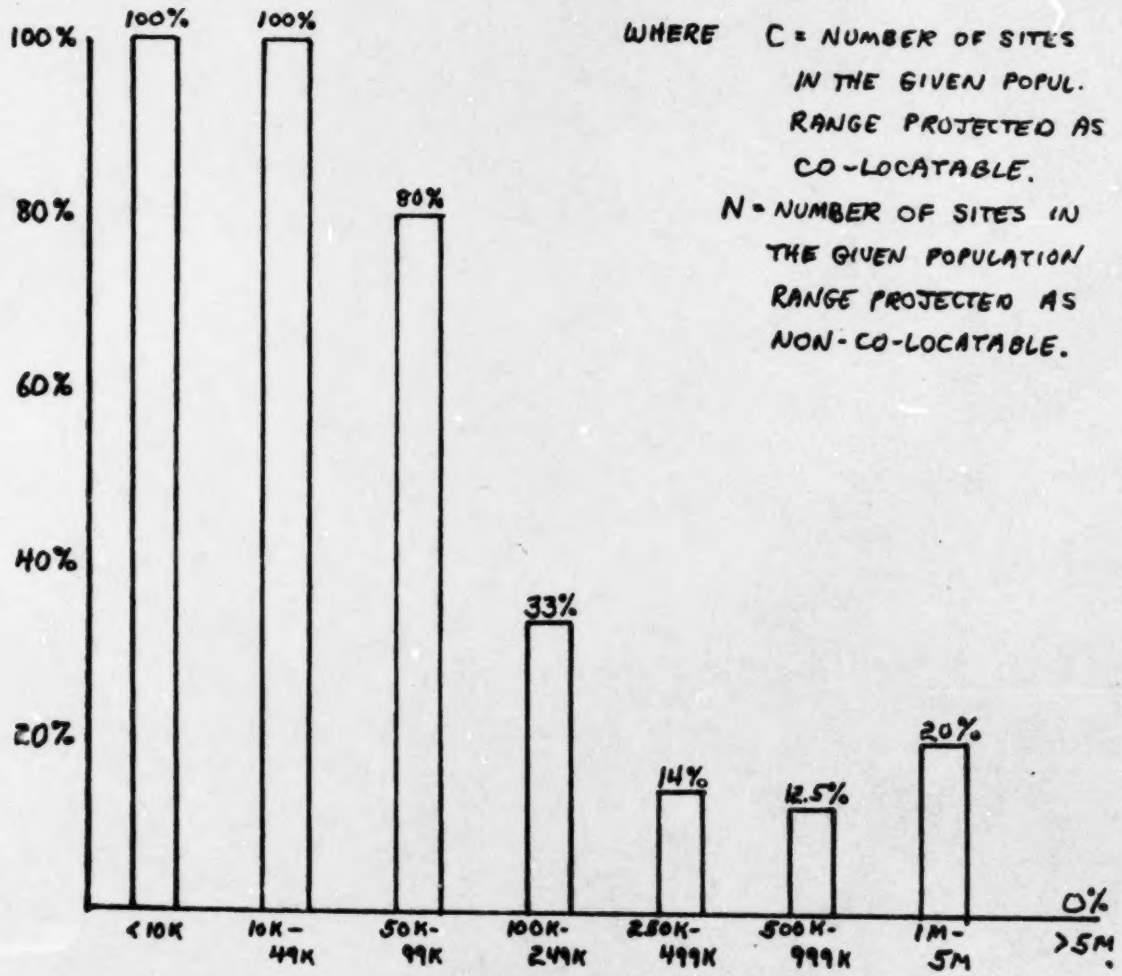
FIGURE II-1

PUBLIC BROADCASTING SITE CO-LOCATION PROJECTION
VS SITE AREA POPULATION

$$\left(X\% = \frac{C}{C+N} \times 100\right)$$

WHERE C = NUMBER OF SITES IN THE GIVEN POPUL. RANGE PROJECTED AS CO-LOCATABLE.

N = NUMBER OF SITES IN THE GIVEN POPULATION RANGE PROJECTED AS NON-CO-LOCATABLE.



regulatory limits on satellite flux density at the earth's surface in this band also impose technical constraints governing minimum antenna size for given performance requirements. For example, Muzak Corporation has tested and proposed a system[2] for distribution of background music using an antenna diameter of four feet. But other applications using larger bandwidths require larger diameter antennas.

[2] ELECTRONICS, January 20, 1977, p. 33

III. A TABULATION OF SOME IMPORTANT CHARACTERISTICS OF FREQUENCY BANDS

A. Capacity

The capacity of the bands being analyzed is summarized in table III-1 listing:

1. Total bandwidth (MHz);
2. Total terrestrial transmit azimuths (U.S.) in current use; (This figure indicates the total number of paths in the band.)
3. Total terrestrial transmit frequencies (U.S.) in current use; and
4. Typical or range of terrestrial channel bandwidth.

Overlaps in frequencies of different bands reflect allocation differences to be explained in the next section. The figures for table III-1 were obtained from computer print-outs from the data base of Compucon, Inc. of Dallas, Tex. Their detailed data are given in the appendix. Five of the frequency bands of interest in this study had no data available in Compucon's data base due to either an allocation to Government use or a predominantly mobile terrestrial use of the band.

B. Current Allocation of Bands

Table III-2 summarizes the allocation and regulatory status of each band. These factors are indicated for ITU region 2 in general as well as the U.S. specifically, and for both satellite and terrestrial services.

Note the overlap in the frequencies of the first two bands. This reflects the allocation of the first band to satellite broadcasting downlink while a portion of the same band, shown in the chart as the second band, is allocated to fixed satellite service uplink.

Another frequency overlap exists between the 6425-6925 MHz and 6625-7125 MHz bands. This results from the 6425-6925 MHz band being under consideration as a fixed satellite service uplink in the U.S. The 6625-7125 MHz band is currently allocated on a secondary basis to fixed satellite service downlink.

FREQ BAND	TOTAL BANDWIDTH (MHz)	TOTAL TRANSMIT AZIMUTHS	TOTAL TRANSMIT FREQUENCIES	TYPICAL CHANNEL BANDWIDTH (MHz)
2500-2690 MHz	190	126	376	5.75
2655-2690 MHz	35	24	57	5.75
3400-3700 MHz	300	NA*	NA*	NA*
3700-4200 MHz	500	9707	68274	20
4400-4700 MHz	300	NA*	NA*	NA*
4700-4900 MHz	200	NA*	NA*	NA*
5925-6425 MHz	500	17611	58860	25-30
6425-6925 MHz	500	11617	11797	10
6625-7125 MHz	500	651 (6925-7125 MHz)	754 (6925-7125 MHz)	10
10950-11200 MHz	250	3184	6251	28-30
11450-11700 MHz	250	3246	6255	28-30
11700-12200 MHz	500	NA*	NA*	NA*
12500-12750 MHz	250	1597	3438	13.08-30
14000-14500 MHz	500	NA*	NA*	NA*

* Information not available

TABLE III-1
Capacity and Usage of Frequency Bands

FREQ BAND	SATELLITE ALLOCATION ITU REGION 2?	U.S. SATELLITE SERVICE ALLOCATION	U.S. TERRESTRIAL SERVICE ALLOCATION
2500-2690 MHz	YES	Broadcasting, Downlink - PFDL	Non-Govt Fixed: ITFS
2655-2690 MHz	YES	Fixed, Uplink	Non-Govt Fixed: ITFS
3400-3700 MHz	YES	NONE	Govt. & Amateur
3700-4200 MHz	YES	Fixed, Downlink - PFDL	Non-Govt Fixed
4400-4700 MHz[1]	YES	NONE	Non-Govt Fixed & Mobile
4700-4900 MHz[1]	NO	NONE	Govt Fixed & Mobile
5925-6425 MHz	YES	Fixed, Uplink	Non-Govt Fixed
6425-6625 MHz[2]	NO	NONE	
6625-7125 MHz	YES	Fixed, Downlink - PFDL	Non-Govt Fixed & Mobile
10950-11200 MHz	YES	Fixed, Downlink - PFDL Internat Oper Only	Non-Govt Fixed
11450-11700 MHz	YES	Fixed, Downlink - PFDL Internat Oper Only	Non-Govt Fixed
11700-12200 MHz	YES	Fixed & Broadcast, Downlink - PFDL	Mobile, (Secondary)
12500-12750 MHz	YES	Fixed, Uplink	Fixed, Mobile (12.7-12.75 Only)
14000-14500 MHz	YES	Fixed, Uplink	Govt Fixed & Mobile

1 4400-4900 is under consideration as non-govt, fixed downlink
2 6425-6925 is under consideration as non-govt, fixed uplink
PFDL - Power Flux Density Limits are imposed

TABLE III-2
Band Allocations

C. Relative Co-location Probability Estimates

Certain bands which are shared with heavily-used terrestrial services pose problems in frequency coordination of a site co-located with the point of use. Table III-3 gives an estimate of the co-location probability. This estimate is based on the observations of the Public Broadcasting activity at 4 GHz (ref. section II-C and Figure II-1) correlated with the current density of terrestrial usage shown in table III-1.

D. Relative Equipment Costs

In addition to a situation of rapid cost fluctuations, other factors of system design complicate a band-by-band comparison of equipment costs. Hence, the discussions in this section must be considered as quite tentative.

While satellite telecommunication in general is still in its infancy, equipments for certain frequency bands exhibit relatively greater cost maturity, due to significant present terrestrial and satellite use. These bands will initially offer some economic incentives for their choice, although changing technology and usage trends may alter the relative cost rankings within a short time.

A useful reference for this section is a paper "Ground Station Hardware Cost/Performance Review and System Considerations Relevant to Orbit-Spectrum Utilization" by Communications Planning Associates of Palo Alto, Calif. According to this report, transmit and receive antennas of the same diameter cost 6 to 20% less at 2.5/6 GHz than at 12/14 GHz, and receive-only antennas at 2.5/4 GHz cost 7 to 27% less than those of the same diameter at 12 GHz. Low noise front end amplifiers typically are a factor of 2 or greater in price at 12 GHz than at 2.5 and 4 GHz. Video receivers, however, are only approximately 7% higher in cost at 12 GHz than at 2.5 and 4 GHz.

FREQ BAND	CO-LOCATION PROBABILITY ESTIMATE
2500-2690 MHz	Downlink - Fair to good probability; Has 3.4% Xmit azimuths per unit bandwidth compared to 4 GHz. However, note the common use of omnidirectional transmit antennas by ITFS systems.
2655-2690 MHz	Uplink - Has 3.5% Xmit azimuths per unit bandwidth compared to 4 GHz.
3400-3700 MHz	Downlink - Not allocated in U.S., no data available.
3700-4200 MHz	Downlink - point of reference for other probability estimates; See Figure II-1.
4400-4700 MHz	No data available.
4700-4900 MHz	No data available.
5925-6425 MHz	Uplink - Has 181% Xmit azimuths per unit bandwidth compared to 4 GHz. Co-location very unlikely.
6425-6925 MHz	Has 120% Xmit azimuths per unit bandwidth compared to 4 GHz. Co-location unlikely.
6625-7125 MHz	Downlink - Good to Excellent probability; Has 16.8% Xmit azimuths per unit bandwidth compared to 4 GHz.
10950-11200 MHz	Downlink - Poor to Fair probability; Has 65.6% Xmit azimuths per unit bandwidth compared to 4 GHz.
11450-11700 MHz	Downlink - Poor to Fair probability; Has 66.9% Xmit azimuths per unit bandwidth compared to 4 GHz.
11700-12200 MHz	Downlink - Excellent probability; Terrestrial use suppressed in U.S.
12500-12750 MHz	Uplink - 32.9% Xmit azimuths per unit bandwidth compared to 4 GHz. Fair to good co-location probability.
14000-14500 MHz	Uplink - No data available.

Notes: Although a simplistic approach, the probabilities above are only given relative to terrestrial congestion.

TABLE III-3
Co-location Probability Estimates

It should be pointed out that the above comparisons are parameter for parameter comparisons that do not take into account large variations in important system factors due to operations on different bands for differing purposes.

E. Technical Constraints

The factors considered here are primarily those technical limitations due to natural causes rather than the effects of immature technology. Although new technology may lessen the impact of these, their presence will always need to be considered.

One of the most significant is the effect of precipitation. Attenuation due to rain is a nonlinear function of frequency and intensity of rain. In general, the higher the frequency, the greater the attenuation for a given rate of rainfall. Also, some frequency reuse systems may be affected by rain-induced cross-polarization which also increases with increasing frequency. A reference on the effects of precipitation is: CCIR XIIIth Plenary Assy., Vol. V., Report 233-3, Geneva, 1974.

On the other hand, higher frequencies result in higher gain for a given antenna diameter, and greater ease in formation of spot beams. For a given size of antenna on a satellite the beam width varies inversely with frequency.

F. Additional Spectrum Considerations

The World Administrative Radio Conference (WARC) of 1979 will afford the opportunity to reexamine and revise the international table of frequency allocations. Preparations in the U.S. for this conference are well under way with voices from many quarters expressing their particular views and interests.

APPENDIX

December 29, 1976

Mr. Dail Ogden
Director of Engineering
Public Service Satellite Consortium
2480 West 26th Avenue
Denver, Colorado 80211

Reference: Additional data on receiver noise figures for the microwave usage summary. Job Number 6344-573

Dear Mr. Ogden:

In our report of December 9, 1976 on the PSSC Microwave usage summary, we omitted data for Task II on the receiver noise figures for typical equipment usages. This information has been collected for various equipment types representing typical equipment usage.

Frequency Band	Equipment Type	Receiver Noise figures including duplexer loss (dB)
1) 2500 - 2690 MHz	No specifications	No specifications
2) 2655 - 2690 MHz	No specifications	No specifications
3) 3700 - 4200 MHz	WE TD-3	7.5 dB
4) 5925 - 6425 MHz	WE TH-3	7.5 dB
	Farinon	9.0 dB
	MW109E-1-R	7.5 dB
	MW 118	9.0 dB
	MW 318	9.0 dB
	775A1	10.0 dB
	KTR3A	11.0 dB
5) 6425 - 6925 MHz	No specifications	No specifications

III. 3700 - 4200 MHz			
Bell System	2 watts	20000F9	2.2° (10')
Indp Tele	5 watts	20000F9	2.2° (10')
Spec C.C.	5 watts	20000F9	2.2° (10')
CATV C.C.	1 watt	20000F9	2.2° (10')
W.U. Sysm	5 watts	20000F9	2.2° (10')
IV. 5925 - 6425 MHz			
Bell Sysm	10 watts	30000F9	1.5° (10')
Indp Tele	2 watts	25000F9	1.5° (10')
Spec C.C.	10 watts	30000F9	1.5° (10')
CATV C.C.	2 watts	30000F9	1.5° (10')
W.U. Sysm	10 watts	25700F9	1.5° (10')
V. 6425 - 6925 MHz			
Business	2.5 watts	10000F9	1.6° (8')
Power	1.5 watts	10000F9	2° (6')
Railroad	2.5 watts	10000F9	1.6° (8')
Public Safety	2.5 watts	10000F9	1.6° (8')
Local Govn	2.5 watts	10000F9	2° (6')
Petrolum	2.5 watts	10000F9	2° (6')
Broadcast	2.5 watts	10000F9	2° (6')
Education	2.5 watts	10000F9	1.6° (8')
VI. 6925 - 7125 MHz			
Broadcast	2.5 watts	10000F9	2° (6')
VII. 10950 - 11200 MHz			
Bell Sysm	.5 watts	28000F9	.8 (10')
Indp Tele	5 watts	30000F9	.8 (10')
Spec C.C.	5 watts	30000F9	.8 (10')
CATV C.C.	5 watts	30000F9	.8 (10')
W.U. Sysm	5 watts	30000F9	.8 (10')
VIII. 11450 - 11700 MHz			
Bell Sysm	.5 watts	28000F9	.8 (10')
Indp Tele	5 watts	30000F9	.8 (10')
Spec C.C.	5 watts	30000F9	.8 (10')
CATV C.C.	5 watts	30000F9	.8 (10')
W.U. Sysm	5 watts	30000F9	.8 (10')

IX. 12500 - 12750 MHz

Cable TV	.4watts	13080F9	.9(8')
Business	.1watts	13080F9	1.(6')
Railroad	-	-	-
Public Safety	2 watts	30000F9	.9(8')
Local Govn	2 watts	30000F9	.9(8')
Petrolum	2 watts	19900F9	1.(6')
Broadcast	.4 watts	13080F9	1.(6')
Education	2 watts	19900F9	.9(8')

If you have any questions concerning the enclosed data summaries, please call.

Sincerely,

Dan Yost

DY/dsh
Enclosure

There is, therefore, a definite incentive for satellite system users to review their options.

This report demonstrates areas of uncertainty in our comprehension of the current scene which warrant some further attention. One evidence of this uncertainty is the inability to find terrestrial usage data in an industry data base concerning five of the fourteen bands investigated here. One reason for this lack is government allocation of certain bands. A future need thus indicated is to determine the extent of activity in government bands, where possible, and to determine and assess the impact of future plans for government communications services in these and other bands. A second reason for the missing data is the predominantly mobile use of some bands. In this case access to FCC licensing records could be of value. A third cause for the lack of information, however, may be simply that certain bands are not being utilized, or are being only slightly utilized.

This low utilization has been suggested in the report "Lowering Barriers to Telecommunications Growth" from the Office of Telecommunications, the Department of Commerce. This report indicated that the bands 3.4 to 3.7 GHz and 4.4 to 4.7 GHz may be unused because of radar and other radio location system within those bands. However, these bands are also sparsely used for terrestrial systems according to the report of the Radio Relay Advisory Committee (Common Carrier) in preparation for the 1977 WARC: "Further analysis was performed on the frequency range 3100 to 3700 MHz and it was found that these bands are very sparsely used relative to the 4 and 6 GHz bands, with the frequency range 3500 to 3700 presently being unused, for all practical purposes. It should be pointed out, however, that the equipments operating in these other bands are

significantly more varied than those operating at 4, 6 and 11 GHz. Radar stations presently operate in the 3.1 to 3.5 GHz band and this, of course, complicates the problem of coordination with other facilities operating in that band." The report, however, goes on to recommend consideration of sharing the band between radar systems and common carrier facilities, particularly for digital systems. In light of the existing ITU region 2 allocation of these bands to satellite use, we might well give them similar attention for satellite digital telecommunications also.

The Department of Commerce report also notes that the bands 10.95 to 11.2 GHz and 11.45 to 11.7 GHz allocated for international satellite operations could be considered for domestic operations on a limited basis. This is based on the present lack of satellite use of these bands. It should be noted (ref. Table III-1) that the terrestrial use of these bands is currently considerable, approaching that of the 4 GHz band in terms of transmit azimuths per unit bandwidth.

The Dept. of Commerce report further indicated that the reasons for the allocation of the unused 6.625 to 7.125 GHz and 12.5 to 12.75 GHz bands are unclear. Both of these bands appear to be rather lightly used by terrestrial systems also.

An important band for which terrestrial usage data is missing is the 11.7 to 12.2 GHz downlink band. It has become clear that use of this band has been extremely slight. The FCC has suppressed terrestrial use of this band in the U.S., but has allowed as a secondary allocation use for mobile television pickup. The report of the Radio Relay Advisory Committee (Common Carrier) in preparation for the 1979 WARC cites a July 1975 survey of the 34 licensees in the local television transmission service. Of the 25 from whom replies were received the report states:

"These carriers had 282 sets of equipment (transmitter-receiver combinations and associated equipment) purchased at an original cost $5,714,239. The 25 carriers indicated that in an average month the equipment would be used to provide service on 323 occasions (237 in the 6 GHz band, 86 in the 11 GHz band) lasting normally from 1 to 3 days per occasion." (The 11 GHz band referenced above is 11.7 to 12.2 GHz.)

IV. PRIORITIZATION OF FREQUENCY OPTIONS FOR PUBLIC SERVICE USERS

A. By Capacity

If total available bandwidth were the only factor the following order might hold:

500 MHz:	3.7 - 4.2 GHz 5.925 - 6.425 GHz 6.425 - 6.925 GHz 6.625 - 7.125 GHz 11.7 - 12.2 GHz 14.0 - 14.5 GHz
300 MHz:	3.4 - 3.7 GHz 4.4 - 4.7 GHz
250 MHz:	10.95 - 11.2 GHz 11.45 - 11.7 GHz 12.5 - 12.75 GHz
200 MHz:	4.7 - 4.9 GHz
190 MHz:	2.5 - 2.69 GHz
35 MHz:	2.655 - 2.69 GHz

Another classification might take into account the current relative terrestrial congestion in terms of terrestrial transmit azimuths and frequencies per unit of available bandwidth:

	BAND	XMIT AZIMUTHS/MHz	XMIT FREQS/MHz
1	11.7-12.2 GHz	(** Terrestrial Use FCC Suppressed**)	
2	2.5-2.69 GHz	.663	1.98
3	2.655-2.69 GHz	.686	1.63
4	6.625-7.125 GHz	1.30	1.51
5	12.5-12.75 GHz	6.39	13.8
6	10.95-11.2 GHz	12.7	25.0
7	11.45-11.7 GHz	13.0	25.0
8	3.7-4.2 GHz	19.4	136.5
9	6.425-6.925 GHz	23.2	23.6
10	5.925-6.425 GHz	35.2	117.7

NO DATA AVAILABLE:
3.4-3.7 GHz
4.4-4.7 GHz
4.7-4.9 GHz
14.0-14.5 GHz

B. By Co-location Probability (For Video Receive-Only Terminals) (Ref. III-C and Table III-3)

	BAND (In order of declining probability)
1.	11.7-12.2 GHz
2.	6.625-7.125 GHz
3.	2.5-2.69 GHz
4.	10.95-11.2 GHz
5.	11.45-11.7 GHz
6.	3.7-4.2 GHz
	NO DATA AVAILABLE: 3.4-3.7 GHz

C. By Equipment Costs

(Ref. III-D) To a first approximation, equipment costs vary inversely with frequency. As noted before, this does not take into account significant differences in system design and relative useage of different frequency bands.

D. By Technical Constraints

	BAND	COMMENTS
1.	2.5-2.69 GHz	Rain attenuation insignificant
2.	11.7-12.2 GHz	Ease of spot beam formation, small antenna
3.	3.7-4.2 GHz	Readily available equipment

E. By Regulatory Constraints

	BAND	COMMENTS
1.	11.7-12.2 GHz	FCC has reserved particularly for satellite communication, no power flux density limits

V. CONCLUSIONS

It appears that the bands 2.5-2.69 GHz and 11.7-12.2 GHz are strong contenders for first place in priority for near future satellite development. However, the band 6.625-7.125 GHz also merits a close look. Overall, it must be remembered that the elements of system design for particular applications may have overriding effects on frequency choice.

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December 9, 1976

Mr. Dail Ogden
Director of Engineering
Public Service Satellite Consortium
2480 West 26th Avenue
Denver, Colorado 80211

Reference: Microwave usage summary by frequency band and user classification
Job Number 6344-573

Dear Mr. Ogden:

As outlined in the PSSC letter of November 1 and our proposal, we have prepared summaries of the microwave frequency usage for nine of the fourteen frequency bands designated in Appendix A of the PSSC letter. The following report provides some useful observations and keys for studying the enclosed data.

Task I

PSSC's task 1 requested summaries of the microwave equipment presently authorized for use in each of the designated frequency bands by counting the number of receivers or transmitters by state and type of user. In addition to providing these summaries, we have also tabulated the number of transmit or receive azimuths for each frequency band by state and type of user. The transmit or receive azimuth summaries provide an indication of the total number of microwave paths while the counts of receivers or transmitters show the density of frequency usage per path and region. Both summaries should be useful in evaluating the suitability of different frequency bands for satellite communication.

For the operational fixed frequency bands, the total number of transmit or receive azimuths is approximately equal to the total number of transmitters and receivers since the majority of these microwave routes assign one frequency per transmit or receive azimuth. The frequency bands used by common carriers will usually assign more than one frequency per azimuth up to the total

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number of assignments allowed per frequency plan. Thus, for 5925-6425 MHz, a carrier has the capability to assign up to eight frequencies per transmit or receive azimuth while observing standard frequency planning practices.

The choice of user classifications was determined by the types of users within each frequency band. In some cases, the distinction between classifications is vague, such as public safety and local government, at 6425-6925 MHz, especially where either classification could be appropriate. We have attempted to select user categories which provide the best profile of the band users. In all summaries, there is a small amount of users who do not fit any of the classifications or who have not been classified. These users are grouped under 'non-class' for non-classified.

The tabulation of the microwave usage summaires has included date on all existing microwave equipment. In addition, the data on microwave applications now on file with the FCC and microwave systems proposed thru the prior frequency coordination procedures are included in the usage summaries.

Task II

In order to specify the characteristics of the typical equipment usage for each frequency band by category of user, we tabulated the usage trends per type of equipment and size of antenna during the data base culls. The following summaries have been condensed from this tabulated data and define the typical equipment characteristics.

Table I — Equipment Characteristics

User Category	Peak transmitter power	Bandwidth	Antenna beamwidth
I. 2500 - 2690 MHz Educational	10 watts	5750A5c	Omin-directional
II. 2655 - 2690 MHz Educational	10 watts	5750A5c	Omni-directional

6) 6925 - 7125 MHz	No specifications	No specifications
7) 10,950 - 11,200 MHz	WE TN1	6.0 dB
	MW 618	10.0 dB
	MW 609E1	11.0 dB
	KTR3A-11	11.0 dB
8) 11,450 - 11,700 MHz	Same as #7	
9) 12,500 - 12,750 MHz	No specifications	No specifications

If you require any additional data, please contact me.

Sincerely,

Dan Yost
Manager of Satellite Services

DY/dsh